

## IMPROVISING NEGATIVE PRESSURE ISOLATION AREAS

TIP No. 98-109-0420

### INTRODUCTION

The Centers for Disease Control and Prevention (CDC) requires negative pressure airborne infection isolation rooms (AIIRs) for patients undergoing aerosolizing procedures such as the use of a ventilator. The American Society of Hospital Engineers (ASHE) states that medical treatment facilities (MTFs) should devise contingency plans for a possible surge in which demand for isolation rooms exceeds capacity, as part of their emergency management plans.

As experienced during the SARS-CoV-1 epidemic in 2004, and as predicted in numerous simulations of severe influenza pandemics, MTFs may face an immediate need to improvise additional negative pressure isolation areas at minimum time and cost.

The purpose of this document is to provide expedient methods for doing so. Methods are provided for normal-care patient rooms and for larger spaces that can be converted to multi-bed isolation areas. These methods have been used during past epidemics or have at least been performance-tested for possible use.

These methods are recommended for emergency and temporary use only, as they generally do not meet the Department of Defense (DOD) or other regulatory requirements for AIIRs. They are not intended to substitute for a properly designed and equipped AIIR if one is available or a full conversion of other spaces to AIIRs. The facilities management team at the hospital should be consulted prior to any changes as they may be able to manipulate the heating, ventilation, and air-conditioning (HVAC) system for various areas to create appropriate isolation areas instead of or in conjunction with these methods. These methods may also be useful in alternative care facilities.

### GENERAL CONSIDERATIONS

The authority having jurisdiction for fire safety should be consulted about all improvised isolation areas because the methods below may interfere with fire and smoke alarm performance, sprinkler discharge, and other life safety provisions. All construction materials must be fire-rated, including plastic sheeting. Please note the temporary fire code provisions in reference 1.

Any proposed improvisation that significantly alters the air balance in one or more rooms should be evaluated by the facilities management team for its effects on the existing HVAC system.

Any exhaust discharge added as part of an improvisation must be a sufficient distance from outside air intakes and other building openings.

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All improvised negative pressure areas must be tested to verify their desired performance before receiving patients and must be retested regularly when in use. See Performance Verification and Monitoring in this TIP.

### **PLANNING FOR IMPROVISED ISOLATION AREAS**

- Recommendations for medical facilities to plan in advance so they can rapidly prepare for emerging infectious disease cases include (reference 2):
  - Reviewing emergency plans, including contingency plans for a possible occurrence in which demand for isolation rooms exceeds capacity.
  - Assessing the current facilities and their capabilities.
  - Ensuring that blueprints of HVAC systems are complete, up to date, and always accessible.
  - Working with all relevant departments to develop a strategy for the rapid construction or conversion of private rooms to disease isolation rooms.
  - Identifying a timeline and responsibilities for construction.
- Improvised negative pressure isolation arrangements in patient bedrooms should meet, as much as is feasible, the design requirements for AIIRs:
  - The CDC requires 12 air changes per hour (ACH) total, 2 ACH of outside air, negative pressurization, and exhaust to the outside (reference 3).
  - For military facilities, additionally, the negative pressurization should be 0.2 inches water gauge (in WG) achieved by starting with a designed 20% excess of exhaust air, and the exhaust should be high-efficiency particulate air (HEPA) filtered unless it can be shown that it will not enter building openings or air intakes (reference 4).
- Room types in order of preference for improvisation are:
  - Normal-care patient rooms
  - Non-patient rooms that are conditioned
  - Large spaces that can accommodate multiple beds (as a last resort)
- General room requirements:
  - The room should be well sealed, or easy to seal, against air leakage. Otherwise, inward leakage of air can defeat an attempt to achieve negative pressurization by mechanical means.
  - The room should not be in an area that is prone to strong drafts from exterior doors and elevator shafts.
  - The room should be easy to disinfect.
  - The room should, if possible, have an operable window that can accommodate a panel with an opening for an exhaust duct or a box fan, and that is a sufficient distance from outside air intakes and other building openings. Stops or other provisions that limit window opening size will need to be removable.

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- The room should be able to be disconnected from systems that recirculate air to other parts of the building, unless contaminated air is treated by a HEPA filtration unit within the room.
- The features of hospital spaces that are good candidates for improvised large isolation areas are (reference 5):
  - Direct access from outdoors and located on the ground floor, to minimize the risk of infection in the remainder of the hospital.
  - At a peripheral part of the hospital to minimize the effect of shutting down existing ventilation systems; at or near the terminal of such systems.
  - Adequate door width, firm exterior pathways, access to emergency medical service (EMS), and ease of stretcher movement as for a hospital emergency exit.
  - Doors or windows that can easily be fitted with panels accommodating ventilation ducts that are as far as possible from any outside air intakes and other building openings.

### **METHODS FOR ACHIEVING NEGATIVE PRESSURIZATION**

- Modification of existing HVAC systems:

Modification of existing HVAC systems to provide negative pressure patient rooms is preferred when feasible, but generally takes more time and effort than is envisaged in this document (reference 6).

- Portable HEPA filtering fan units:

Many hospitals have these on hand, often for construction purposes. There are multiple ways in which they can be used as described below. Guidelines for their use and maintenance are provided in reference 4. Their electrical requirements should be evaluated, and risks from operating them in oxygen-rich environments should be assessed. They should be thoroughly cleaned and disinfected, with new pre-filters installed and should be performance-tested before use. Detailed instructions for selecting and preparing units for use are provided in Appendix A.

The HEPA units may discharge through a window panel, into the return air grille, or into the room. The first two options provide negative pressurization, but their effects on the air balance in other rooms have to be considered. The exhaust, via a window panel, should be screened against pests, and rain entry needs to be considered (references 7-10). Instructions for directing the HEPA exhaust into the existing return air grille are provided in reference 7. This may, however, pressurize the return air system and interfere unacceptably with the air balance in other rooms.

A disadvantage of discharging filtered air within the room is that it does not, in itself, provide negative pressurization in the remainder of the room, and might actually provide positive pressurization, if existing return air grilles are blocked off. Protection from pathogens in the remainder of the room and possibly in the adjacent corridor and rooms is entirely dependent on the proper maintenance of the HVAC filtration unit.

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- Window-mounted propeller fans:

If there are no HEPA filtering units available, commercial-grade propeller fans mounted in operable windows are a potential last resort for providing negative pressure. Some improvisations using these fans are described below. The exhausted air cannot be properly filtered because of the limited pressure drop capacity of these fans. It is recommended that unfiltered exhaust air be discharged at least 25 feet (ft) from building air intakes and openings with careful consideration given to wind and air currents (reference 7). Important considerations for use of these fans are noise, room temperatures, proper installation, effects on air balance and providing sufficient make-up air.

### **IMPROVISATIONS IN NORMAL-CARE PATIENT ROOMS**

- General:

The ideal improvised arrangement is a portable HEPA filtration unit that draws from the head of the bed and is equipped with a bypass that diverts some of the air to an exhaust duct to provide negative pressurization. This requires a unit so equipped and an operable window in which a panel may be placed so that the exhaust duct can be vented outside.

Bathroom exhaust may be useful in creating negative pressure for the room, but the discharge of the exhaust system and its proximity to building air intakes and occupied areas should be considered. Warnings to maintenance workers should be issued and posted because of the potential hazard of a contaminated airstream.

Modifications must be done in coordination with facilities management personnel as they will affect air balance and temperature and humidity control.

If the window is sealed, the unit will have to discharge into the room or into the return air grille. If the window is operable and the unit is not equipped with a bypass, the unit may be exhausted outdoors via a panel fitted and sealed within the window opening. Discharge into the return air grille and to the outside are described in references 7 and 10. Return air grilles must be blanked off if the unit discharges outside. If discharge is into the return air grille, it must be ducted and the grille otherwise well sealed.

- Vestibule with HEPA filtration unit:

A vestibule can be constructed at the door to a normal-care patient room, or a prefabricated portable vestibule can be installed with a HEPA filtration unit blowing out into the corridor if space permits. The vestibule should be at least 6 ft wide by 3 ft deep, with a 5 ft wide opening to accommodate bed movement. The vestibule must be sealed to the corridor wall, and the return air grille in the room must be sealed. The patient room door is left open unless it is fire-rated (reference 10).

- Curtain negative pressure isolation zones:

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Plastic sheeting can be suspended from existing privacy curtain hooks in normal-care patient rooms to provide localized negative pressurization zones, exhausted by a portable HEPA filtration unit discharging into the room (references 7, 10, and 11). The sheeting extends to the floor and is taped down or ballasted with a chain along the bottom to keep it in place against the negative pressure inside. The small gap above the curtain rail is blocked by a strip of plastic. Makeup air is provided by leaving the curtain slightly open at the head of the bed where the caregivers will be operating. The bed should be fitted with skirting to prevent air bypassing the patients head position. A single HEPA unit can serve both beds in a semi-private room. Supply air from outlets inside the zone(s) will have to be diverted into the remainder of the room to avoid disrupting the airflow pattern. Return air grilles should be sealed. The units should be tested prior to and periodically during use, including visualization testing and performance testing of the HEPA filter. Some configurations that have been tested in the field are shown in reference 12.

- Ventilated headboard with hood:

Another approach to providing a negative pressure zone in a normal-care patient room is a ventilated headboard with a retractable hood connected to a portable HEPA filtration unit providing 12 room ACH and discharging into the room. Detailed instructions for building one are provided in reference 13. These headboards operate at a low-capture velocity of 30 feet per minute. The arrangement is, therefore, sensitive to disturbances from doorway operation, personnel movement, and room ventilation air currents. Raising the head of the bed will cut off some of the coverage. The units should be tested prior to and periodically during use, including visualization testing and performance testing of the HEPA filter. Some configurations that have been tested in the field are shown in reference 12.

## **IMPROVISED MULTI-PATIENT ISOLATION SPACES**

- Large open areas in a hospital:

The conversion of a 2,930 square feet (ft<sup>2</sup>) hospital physical therapy gym into a large isolation area using four portable HEPA units that exhausted via individual ducts through a plywood insert set into an exterior doorway was tested. The existing ventilation inlets and outlets were sealed. It was roughly estimated that the room could contain 30 beds. The units created more than 12 ACH and a negative pressure of 0.02 inches wg, exceeding DOD and NIOSH guidelines (reference 2). This approach provides negative pressurization for multiple beds using a minimal number of portable HVAC filtration units. A disadvantage is that patients with airborne diseases, in addition to the targeted one, are likely to spread them to other patients, so this approach should be used as a last resort in a mass casualty situation.

An alternative that provides individual negative-pressure isolation enclosures within a large area was tested. Three conjoined enclosures of 12.5 ft x 8.5 ft x 8.5 ft high, one with a small anteroom, were constructed with plastic sheet walls and ceilings and ventilated by a portable HEPA-filtered unit discharging into the larger space (reference 14). Note that the ceilings interfere with fire and smoke sensors and sprinkler operation, so these cubicles will not meet fire codes and pose a substantial fire risk, especially where oxygen must be administered.

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- **Multi-Patient Wards:**

Improvised negative pressure areas were provided in a multistory normal-care ward of a hospital that was assigned to receive Severe Acute Respiratory Syndrome (SARS) patients. The windows in each room were operable. A 14" box fan was placed in each window and cloth placed to seal the entrance doors to achieve a negative pressure in the range of 0.028 to 0.07 in wg. Air change rates were not stated. Stairways between the floors were closed. The existing air-conditioning systems continued to operate because of hot and humid weather. This facility was used for initial intake and for patients with mild symptoms. Patients were transferred to larger medical centers with AIIRs if they showed significant respiratory deterioration (reference 15).

Computerized fluid dynamics (CFD) were used to evaluate the conversion of a six-person general ward into an improvised isolation area by installing two 12 inch (in) box fans in otherwise sealed windows, as had been actually done to handle SARS patients. The air exchange rate was higher than 12 ACH, and negative pressurization (level not stated) was achieved. A standard AIIR was evaluated for comparison. The improvised isolation area was found to perform at least as well as the AIIR in removing microbial contamination. The disadvantage is the potential transmission of additional diseases among the up to six patients (reference 16).

Cubicles may be formed in a larger space with operable windows using window-mounted fans to provide exhaust and negative pressurization. It was recommended that fans be rated at 50% above the airflow required to achieve 12 ACH due to real world decrements in performance. It was recommended that a hinge stop be provided on the doors leading into the area be adjusted so that the doors are slightly ajar when the fans were working properly (reference 17).

- **Anterooms:**

An anteroom is recommended to separate multi-patient isolation areas from the rest of the building. The anteroom should have enough space for PPE storage and changing and for waste disposal. It should be pressurized by a portable HEPA unit drawing air into the HEPA filter from the patient isolation room and the filtered exhaust discharged into the anteroom. An airtight seal should be made for all connections. The size of the doorway must accommodate movement of equipment, possibly including beds. Both doorways (to the anteroom and the patient area) should never be open at the same time (references 5, 7, and 10).

- **Ganged headboard ventilation systems:**

Several headboard ventilation systems as described in Ventilated Headboard with Hood in this TIP can be ducted to be served by one large HEPA filtration unit, with instructions provided in reference 13. Instructions are also provided for isolation tents to further enclose individual beds.

## **IMPROVISED ASSESSMENT/TRIAGE FACILITIES**

- General:

Designate an area at the facility (e.g., an ancillary building or temporary structure) or identify a location in the area to be a “respiratory virus evaluation center” where patients with fever or respiratory symptoms can seek evaluation and care.

If possible, install physical barriers (e.g., glass or plastic windows) at reception areas to limit close contact between triage personnel and potentially infectious patients. Consider establishing triage stations outside the facility to screen patients before they enter. To the extent possible, follow airborne precautions as identified by CDC.

- Improvisation in an ambulance bay:

An assessment facility for incoming potential SARS patients was built inside an ambulance bay within a week. Metal pipe framing was used to support plastic walls and ceilings for eight negative pressure cubicles with a common exhaust system. Spaces were designated for clerical work, personal protective equipment (PPE) change-out, and case assessment. A lead-lined X-ray room and an X-ray viewing room were also provided. A minimum of six ACH was provided in each cubicle using an improvised exhaust system (reference 2). Note that the ceilings interfere with fire and smoke sensors as well as sprinkler operation, so a careful fire watch is required.

- Booths:

One hospital in South Korea has developed a “phone booth” setup that allows healthcare workers to collect samples while remaining isolated from patients under investigation. Descriptions, photographs, and a video clip can be found in references 18-20. Each booth can accommodate one patient per 24 minutes, including disinfection operations between patients.

## **PERFORMANCE VERIFICATION AND MONITORING**

The performance of improvised negative pressure spaces should be verified before use and monitored daily if possible. Verification and monitoring should include manometers or visual indicators (e.g., smoke tubes, flutter strips, and so forth) (reference 21).

Refer to Appendix A for detailed instructions for verifying and monitoring the performance of HEPA filtration units.

Useful instructions for particle counters to test the performance of HEPA filters on filtration units (including acceptable criteria) and for the use of manometers are provided in reference 7.

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## **APPENDIX A**

### **Considerations for the Use of Portable HEPA Filtration Units (references 7, 9, and 21)**

Ensure a sufficient supply of the correct filters needed for change-out of both the pre-filter and HEPA filter.

Clean and disinfect any portable HEPA units that have been used previously; follow manufacturer's instructions and guidance for installation of new pre-filters and, if necessary, HEPA filters. Portable HEPA filtration units should be performance-tested before use (see appendix G of reference 7).

Portable HEPA filtration units should be capable of recirculating all air in the room. Select the correct size portable HEPA filtration unit by calculating the desired air exchange rate for the individual room or area. For example, if 12 ACH is desired and the room size is 20 ft x 15 ft x 10 ft or 3000 cubic feet (ft<sup>3</sup>), the airflow volume should be calculated as follows: 12 ACH ÷ 60 min x 3000 ft<sup>3</sup> or 600 cfm.

These units usually have multiple speed selections. It is desirable to operate them at the lowest possible speed that will achieve the desired airflow in order to minimize noise. A HEPA filtration unit should ideally be rated to supply 25% more air than the 12 ACH desired at its low speed setting; this will help to keep noise levels down and to account for loading up of the filters, as well as a possible shortfall in its actual versus rated performance due to ductwork and other factors (reference 6).

Consider existing room ventilation when ducting the portable HEPA unit to a return air duct. For example, ducting a 600 cubic feet per minute (cfm) portable HEPA filtration unit to a return that normally returns 300 cfm of air will over-pressurize the duct and affect the airflow and pressurization of adjacent rooms.

Portable HEPA filtration units must be located to avoid blocking egress per the Life Safety Code® and local requirements.

Other considerations to effectiveness of the units, according to CDC are: room configuration, furniture and people in the room, placement of units relative to room layout, and location of supply and exhaust grilles. The unit should be as close as possible to the source (patient) and should not pull contaminated air past the healthcare workers. Avoid directing clean airflow onto patients or staff to avoid discomfort.

Consider electrical requirements for the filtration unit and consult safety personnel for the use of extension cords. Also, consider if the unit is required to connect to the ESS system.

Ensure preventive maintenance and correct PPE for workers performing maintenance on the units.

Obtain the correct filter change requirements (both for the pre-filter and the HEPA filter) from the portable HEPA unit manufacturer. Ensure staff are aware of these requirements. Pressure drop

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should be verified periodically to ensure compliance with manufacturer's instruction on filter changes and to ensure the unit is not leaking.